

sights themselves are so beautiful and interesting that no other incentive is needed. This morning I showed — a magnificent prominence upwards of 3' in height; and she testifies that my sketches do not do them justice.

The instrument I am now using is the Royal Society's spectroscope as fitted up for the eclipse; but I have increased the dispersion nearly three-fold by inserting four compound prisms (extracted from the hand-spectroscopes). These amount to 7 inches of glass and sixteen surfaces; so you may imagine that there is some loss of light and definition. I have also had to shorten the focal distance (and therefore diminish the magnifying-power) by interposing a hand-telescope's object-glass—an additional obstruction and complication. I lost a great deal of fine weather (of which I get very little now) while trying to perfect this arrangement. I can still further increase the dispersion (without much loss of definition for *monochromatic light*) by turning the main prism, and so departing from the position of minimum deviation. But this is a resource which I keep to go on with when I tire of the advantage I have gained already.

The long train of compound prisms (as at present arranged) unfortunately bars me from the violet end of the spectrum. This is unfortunate, as it would be in the highest degree interesting to compare the α and γ images. Some day I shall get impatient, pull the whole affair to pieces, and arrange afresh with this object. As it is, I have to be very chary of quitting beaten ground, as we boast of no instrument-makers here!

I wish I had time to write fully and connectedly on the subject. It is only necessary to put people on the track. It is one easily followed, and will amply repay any expenditure in arranging prisms to get a maximum dispersion, for there is any amount of light.

XXVII. "Some Experiments with the Great Induction Coil at the Royal Polytechnic." By JOHN HENRY PEPPER, F.C.S., Assoc. Inst. C.E. Communicated by J. P. GASSIOT, Esq. Received June 12, 1869.

The length of the coil from end to end is 9 feet 10 inches, and the diameter 2 feet; the whole is cased in ebonite; it stands on two strong pillars covered with ebonite, the feet of the pillars being 22 inches in diameter. The ebonite tubes &c. are the largest ever constructed at Silver-Town Works.

The total weight of the great coil is 15 cwt., that of the ebonite alone being 477 pounds.

I am indebted to Mr. Apps for the following details. The primary wire is made of copper of the highest conductivity, and weighs 145 lbs.; the diameter of this wire is .0925 of an inch, and the length 3770 yards. The number of revolutions of the primary wire round the core of soft iron is 6000, its arrangement being 3, 6, and 12 strands.

The total resistance of the primary is 2·201400 British Association units ; and the resistances of the primary conductors are, respectively, for three strands ·733800 B.A.U., six ·366945 B.A.U., twelve ·1834725 B.A.U.

The primary core consists of extremely soft straight iron wires 5 feet in length, and each wire is ·0625 of an inch in diameter. The diameter of the combined wires is 4 inches, and their weight is 123 lbs.

The secondary wire is 150 miles in length ; it is covered with silk throughout ; and the average diameter is ·015 of an inch.

The total weight of this wire is 606 lbs., and the resistance 33,560 B.A. units. The insulation throughout is greater by 95 per cent. than the strain upon the coil during its action. The secondary wire is insulated from the primary by means of an ebonite tube $\frac{1}{2}$ an inch in thickness and 8 feet in length.

The length of the secondary coil is 54 inches, the diameter is 19 inches, and, without the internal ebonite tube containing the primary wire and iron core, it is a hollow cylinder 19 inches in diameter and 6 inches thick.

The condenser, made in the usual manner with sheets of varnished paper and tinfoil, is arranged in six parts, each containing 125 superficial feet, or 750 square feet of tinfoil in the whole.

A large and substantially made Contact-breaker, detached from the great coil and worked by an independent electromagnet, was constructed, and worked very well with a comparatively moderate power of 10 or 20 large Bunsen's cells ; when, however, the battery was increased to 30 or 40 cells, it became unmanageable.

A Foucault break, with the platinum-amalgam and alcohol above it, was now tried, and answered very much better than the ordinary contact-breaker : there was no longer any burning or destruction of the contact points, although the great power of the instrument appeared to cause continued decomposition in the water of the alcohol placed above the platinum amalgam, and the spirit was frequently ejected, probably by explosion of the mixed gases taking place in the amalgam, in which they collected in bubbles ; the alcohol took fire constantly, and had to be extinguished. A large and very strong glass vessel (in fact the inverted glass cell of a bichromate battery) was bored through, and the neck fitted into a cap with cement, a thick wire covered with platinum being inserted in the cap ; the platinum amalgam was poured on this, and over it a pint of alcohol ; the contact wire was also very large, and pointed with a thick stud of platinum, and, being attached to a spring, contact was easily made and broken. Flashes of light could be seen between the amalgam and the alcohol ; but explosions did not occur, and the height of the column of the latter prevented the forcible ejection of the spirit, which no longer took fire. This break was used for eight hours in a continuous series of experiments.

The Bunsen's battery used in the experiments was made with the largest porous cells that could be obtained, and each cell contained about one pint of nitric acid, the immersed carbon being 50 superficial inches in each cell.

The resistance of a single cell of this large Bunsen battery was found to be .2585 B.A.U.

In the following experiments the battery was arranged for intensity, and used with the complete condenser of 750 square feet of tinfoil and 2000 square feet of paper in 1500 sheets.

Number of cells of battery.		Length of spark. inches.	
5	 complete condenser	.....	12·0
10	..... „ „	.....	14·0
15	..... „ „	.....	17·5
20	..... „ „	.....	21·25
25	..... „ „	.....	23·0
30	..... „ „	.....	23·5
35	..... „ „	.....	26·0
40	..... „ „	.....	27·5
50	..... „ „	.....	28·0 to 29·0

The longest spark yet obtained is therefore 29 inches in length.

In order to ascertain whether any variation in the size of the condenser (of which, as already stated, 1, 2, 3, 4, 5, or 6 parts could be used) would affect the length of the spark, a number of experiments were tried; and it will be noticed in the tabulated results that when half the condenser was used the spark increased in length up to 20 cells, but not after. The experiment of dividing the condenser and using one half led to a very serious accident, and the coil was rendered useless for a time by the destruction of the insulating material of a part of the primary coil; the particular strands affected threw out minute spicula of metal, which communicated with each other, and the battery-current, instead of passing through 1257 yards, now only traversed a very short length. The accident, however, proved to be useful, inasmuch as it showed that the coil could be easily taken to pieces and repaired in a comparatively short space of time. In the annexed Table the experiments with the half of the condenser are marked with a cross.

Number of cells.		Length of spark. inches.	
5	 full condenser	.....	12·00
„	 reduced $\frac{1}{6}$	.....	10·75
„	 „ $\frac{2}{6}$	.....	13·00
„	 <i>one-half</i> or $\frac{3}{6}$ ..... +	.....	13·50
„	 reduced $\frac{4}{6}$	.....	13·00
„	 „ $\frac{5}{6}$	.....	11·75
10	 full condenser	.....	14·00
„	 reduced $\frac{1}{6}$	.....	15·00
„	 „ $\frac{2}{6}$	.....	15·75

		inches.
10	 <i>one-half</i> $\frac{3}{8}$ +.....	18·00
„	 reduced $\frac{1}{8}$	17·25
„	 „ $\frac{5}{8}$	17·
20	 full condenser	21·25
„	 reduced <i>one-half</i> +.....	22
30	 full condenser	23·5
„	 reduced <i>one-half</i> . +.....	23·5
40	 full condenser	25·0
„	 <i>one-half</i> +.....	25·0
50	 full condenser	28
„	 <i>one-half</i> +.....	28

Experiments were now tried to ascertain whether any increase in the length of the spark could be obtained by arranging the battery and the primary coil for *quantity*.

	inches.
5 + 5 cells, length of spark	14·5
10 + 10 cells, „	18·0
20 + 20 cells, „	21·75
25 + 25 cells, „	23·75
15 + 15 + 15 cells, „	20·00

It is evident that no material advantage was obtained by the above arrangement except in the first experiment; and even where three groups were connected, as in the last experiment, a decrease in the length of the spark is observed when compared with the 45 or 50 cells arranged for intensity, the difference being as 20 to 28.

The spark obtained from the large coil presents some novel and curious features. It is thick and flame-like in its appearance, and therefore it will be alluded to as the “flaming spark.”

When the discharging-point and circular plate are brought within 6 or 7 inches of each other, the flaming nature of the spark becomes still more apparent.

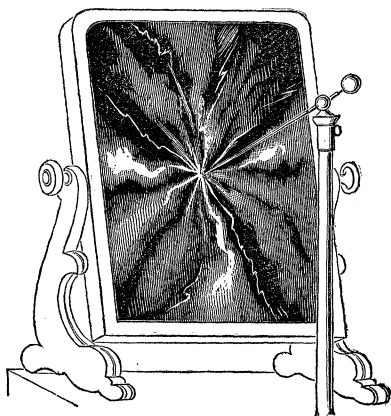
Two light yellow flames curving upwards appear to connect the opposite poles. If a blast of air from powerful bellows is directed against the flaming spark, the flaming portion can be blown away and increased in area; and thin wiry sparks are now seen darting through it, sometimes in one continuous stream, at another time divided into three or more sparks, all following the direction in which the flame is blown.

The heat of this is very great, and, if passed through asbestos (supported on an insulating pillar), quickly causes the latter to become red-hot.

When powdered charcoal is shaken from a pepper-box into the flaming

spark in a vertical line and in considerable quantities, the greater part of the light is obscured, and the whole form of the flaming spark presents the appearance of a black cloud with a line of brightly ignited particles fringing the lower parts. If the charcoal is dusted through in small quantities, each particle becomes ignited, like charcoal blown into a hydrogen-flame.

When the flaming spark is directed on to a glass plate upon which a little solution of lithium chloride is placed, the latter colours the flame upwards to the height of 3 or 4 inches in the most beautiful manner; and if the point of the discharge is tipped with paper or sponge moistened with a little solution of sodium chloride, the two colours (the yellow from the salt and the crimson from the lithium) meet each other, a neutral point being found about halfway, thus illustrating apparently the dual character of electricity, and that $+$ passes to $-$ electricity, and *vice versa*.



The flaming spark can be obtained in perfectly dry air.

Whilst passing through common air, if blown against a sheet of damp litmus-paper, the latter is rapidly changed red. In order to ascertain whether the acid product was nitric acid, the flaming spark (9 or 10 inches in length) was passed through a tube connected by a cork and bent tube with a bottle containing distilled water, from which another tube passed to the air-pump; on drawing the air slowly over the spark, and passing the former into the bottle, nitric acid was obtained in large quantities—so much so that it could be detected by the smell and taste as well as by the ordinary tests. The popular notion that nitric acid is always produced during a thunder-storm would therefore appear to be correct. To determine the effect of a cooling surface on the flaming spark, a hole one inch and a half in diameter was bored through a thick block of Wenham-lake ice, and the spark passed through the air in the tube of ice; no change took place, and the spark was still a flaming one.

When the spark was received on the ice, it lost its flaming character, and became thin and wiry, spreading out in all directions.

If the discharging-wires were tipped with ice, the spark was always flaming when any thickness of air intervened between them. Even over the ice, if the spark passed a fraction of an inch above the surface, it was always a flaming one, but changed to the thin spark when the point of the discharging-wire was thrust into the ice.

If one of the discharging-wires of the great coil is brought to the centre of a large swing looking-glass and the other wire connected with the amalgam at the back, the sparks are thin and wiry, arborescent, and very bright (see figure, p. 69), the crackling noise of these discharges being quite different from that of the heavy thud or blow delivered by the flaming spark.

When the discharging-wire is brought close to the frame of the looking-glass, or if a sufficient thickness of air intervenes, the spark again becomes flaming; or, as sometimes occurs, if the discharging wire is placed about 5 inches from the frame, the spark is partly flaming and partly wiry, *i. e.* when it impinges on the glass.

The examination of the flaming spark with the spectroscope has not as yet settled anything definitely. The spectrum is a continuous one with the sodium-line. When the blast of air is used, and the wiry sparks made apparent, then the nitrogen line appears.

The flaming spark has been ascribed by some experienced observers to the incandescence of the dust in the air, and especially sodium chloride.

If the salt &c. is thus made hot, can the air in which it is mechanically diffused remain cool?

Is not the salt &c. in the same condition as a platinum-wire held in the non-luminous part of the hot burnt gas escaping from the chimney of an Argand burner?

Will gaseous elements when combining (and in this case the nitrogen and oxygen do unite, as proved by the formation of nitric acid) give a continuous spectrum?

To ascertain whether the "flaming spark" could be obtained with a small number of cells, the large Bunsen's battery was reduced to 3 cells; and it was found that no appreciable spark could be produced when the whole primary wire was used with less than 5 cells.

By reducing the length of the primary wire, and using the 4 divisions separately, the following results were arrived at:—

5 cells.		inches.	
1st section, nearest core	.....	$4\frac{1}{2}$	wiry spark.
2nd "	.....	$6\frac{1}{2}$	" "
3rd "	.....	$4\frac{3}{4}$	" "
4th "	.....	$6\frac{1}{2}$	" "

10 cells.

	inches.	
1st section, nearest core	$8\frac{1}{8}$	wiry spark.
2nd „	$8\frac{3}{4}$	„ „
3rd „	8	bright blue wiry spark.
4th „	$9\frac{3}{4}$	slightly flaming.

15 cells.

	inches.	
1st section, nearest core	10	slightly flaming.
2nd „	$10\frac{7}{8}$	„ „
3rd „	$9\frac{3}{4}$	„ „
4th „	$11\frac{5}{8}$	flaming spark.

20 cells.

	inches.	
1st section, nearest core	$11\frac{1}{2}$	flaming spark.
2nd „	12	„ „
3rd „	11	„ „
4th „	$12\frac{1}{2}$	„ „

If the two wires from the secondary coil are placed in water, no spark is perceptible, even when they are brought very close together, until they touch.

If the negative wire is passed through a cork, on which a glass tube (a lamp-glass) is fixed containing a depth of 5 inches of water, and the positive wire is brought within half an inch of the surface of the water in the tube, it becomes red-hot; and if drawn further away from the surface, the upper part of the tube is filled with a peculiar glow or light abounding in Stokes's rays.

The experiments with the vacuum-tubes, and especially Gassiot's cascade, are, as might be expected, very beautiful. When a coal-gas vacuum-tube of considerable diameter, and conveying the full discharge from the secondary coil, is supported over a powerful electromagnet axially, the discharge is condensed and heat is produced.

If placed equatorially, the heat increases greatly; the discharge is condensed and impinges upon the sides of the glass tube, which becomes too hot to touch; and if the experiment had been continued too long, no doubt the tube would have cracked.

The enormous quantity of electricity of high tension which the coil evolves when connected with a battery of 40 cells, is shown by the rapidity with which it will charge a Leyden battery.

Under favourable circumstances, three contacts with the mercurial break will charge 40 square feet of glass.

Mr. Gassiot was present on one occasion, and particularly observed with myself the rapidity with which a series of 12 large Leyden jars arranged in cascade were discharged. The noise was great; and each time the spark (which was very condensed and brilliant) struck the metallic disk, the latter emitted a ringing sound, as if it had received a sharp blow from a small hammer.

The discharges were made from a point to a metallic disk; and when the former was positive the dense spark measured from $18\frac{1}{2}$ to $18\frac{3}{4}$ inches, and fell to $8\frac{1}{2}$ inches when the metallic plate was positive and the point negative.

A variations of the Leyden-jar experiments was tried, by connecting the coil worked by a quantity battery of $25+25$ cells with six Leyden jars arranged in cascade; and the spark obtained measured $8\frac{1}{2}$ inches.

The same six jars connected with the coil when the 50 cells were arranged continuously for intensity gave a spark of 12 inches of very great density and brilliancy.

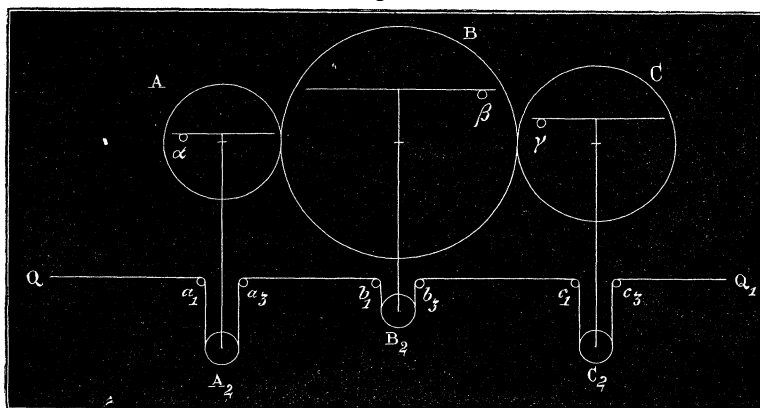
Other experiments are being tried with the great coil, the results of which will be duly brought before the Society if thought of sufficient importance.

XXVIII. "On the Mechanical Description of Curves."

By W. H. L. RUSSELL, F.R.S. Received June 17, 1869.

Let A, B, C be three wheels rolling in one another (fig. 1); they may of course be supposed to describe simultaneously the angles $m\theta$, $n\theta$, $r\theta$, when m , n , and r are constant.

Fig. 1.



Let α , β , γ be three nuts situated on A, B, C respectively, at distances a , b , c from their centres. Then if these nuts work in horizontal bars (as exemplified in many sewing-machines), the bars will descend vertically

